Robotics at the Extremes

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Extremes

LAND
SEA
AIR
SPACE

Cryo Cold
Torrid Heat
Radiation
Vacuum
Pressure
Toxicity
Energetics
Scale

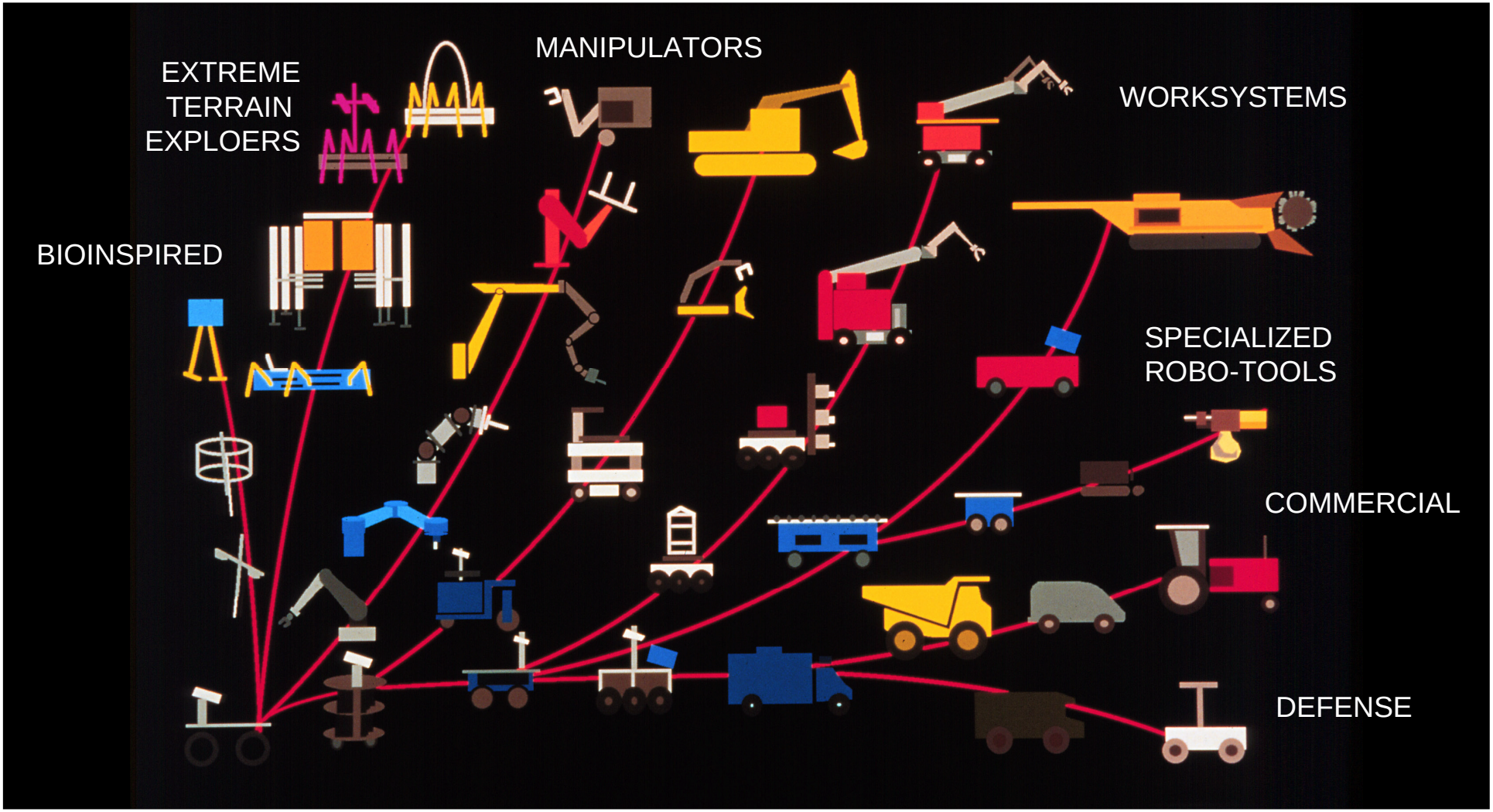
Arctic
Antarctic
Deserts
Volcanoes
Canyons
Craters
Oceans
Hot Springs
Vents

Battlefield
NBC Plants
Mines

Motivation for Robotics

- Environments unnatural to humans
- Challenging to hazardous to fatal
- Hard access or unreachable
- Dynamic, unpredictable
- Humans in suits
- Insufficient technology
- Hard sensory and task requirements

Robotic Evolution



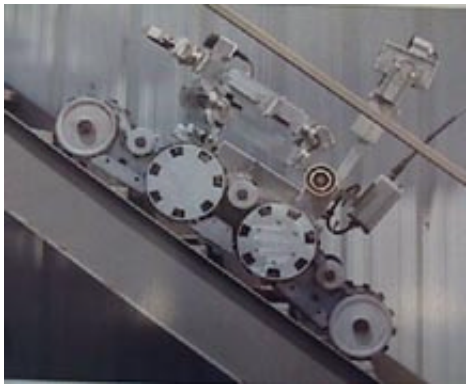
Technical Distinctions, Geometric Growth

Defense & Law Enforcement Robotics

Navlab (reconnaissance)

URBIE (urban reconnaissance)

RATLER (reconnaissance)

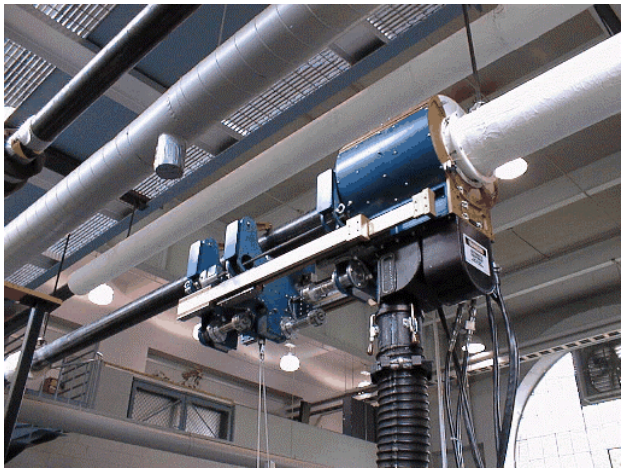


Andros (bomb disposal)

BUGS (UXO detection)

DarkStar (reconnaissance)

Hazardous Duty Robotics



BOA (asbestos removal)

Automated Underground Miner

Houdini (hazardous waste clean-up)

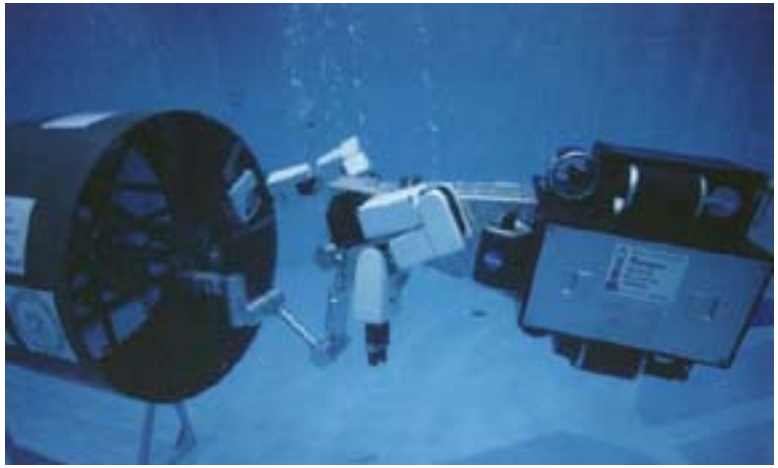
Rosie (dismantlement ops)

Pioneer (Chornobyl stabilization)

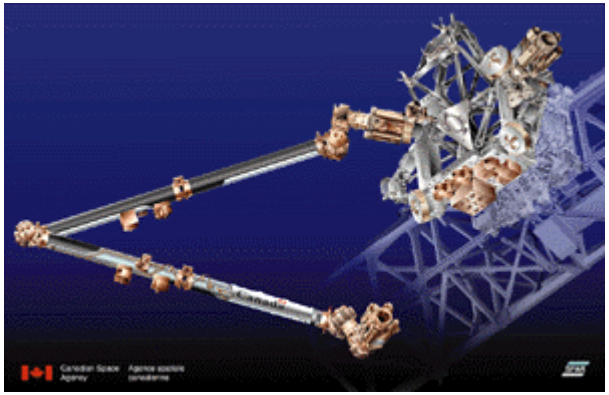
Orbital Robotics

Space Shuttle RMS

Ranger



AERCam Sprint

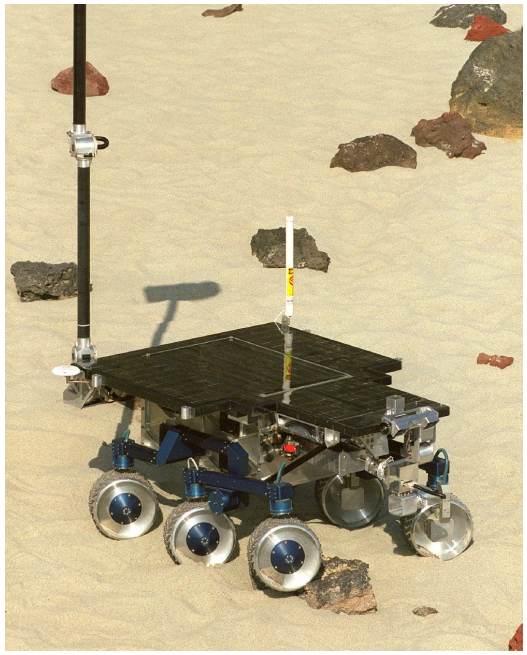


Mobile Service System

Special Purpose Dexterous Manipulator

Planetary Robotics

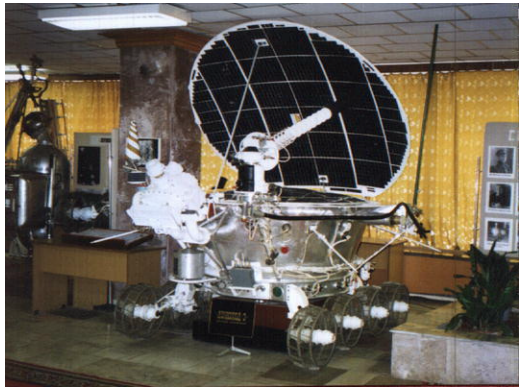
Sojourner



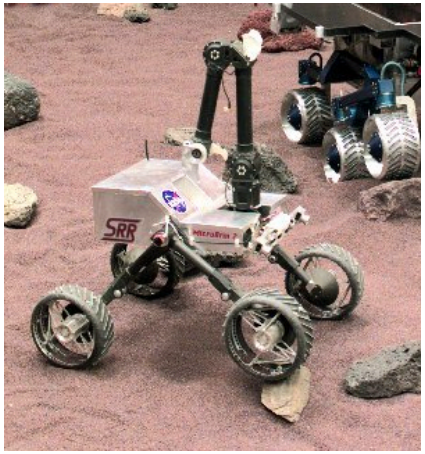
Prototype Athena MER

Inflatable Rover

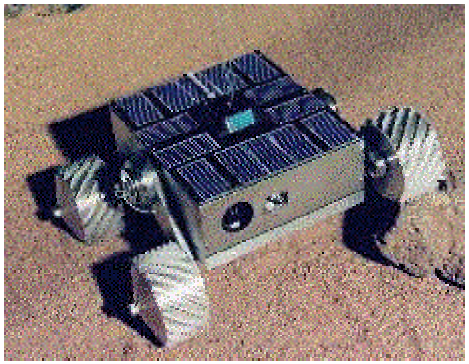
Tri-Star



Lunokhod



LSR Robotic Rover



Nanorover

Marsokhod

Robotics in Planetary Analogs

Dante, Mount Erebus, 1992

Dante II, Mount Spurr, 1994

Nomad, Atacama Desert, 1997

Nomad, Patriot Hills, Antarctica, 1998

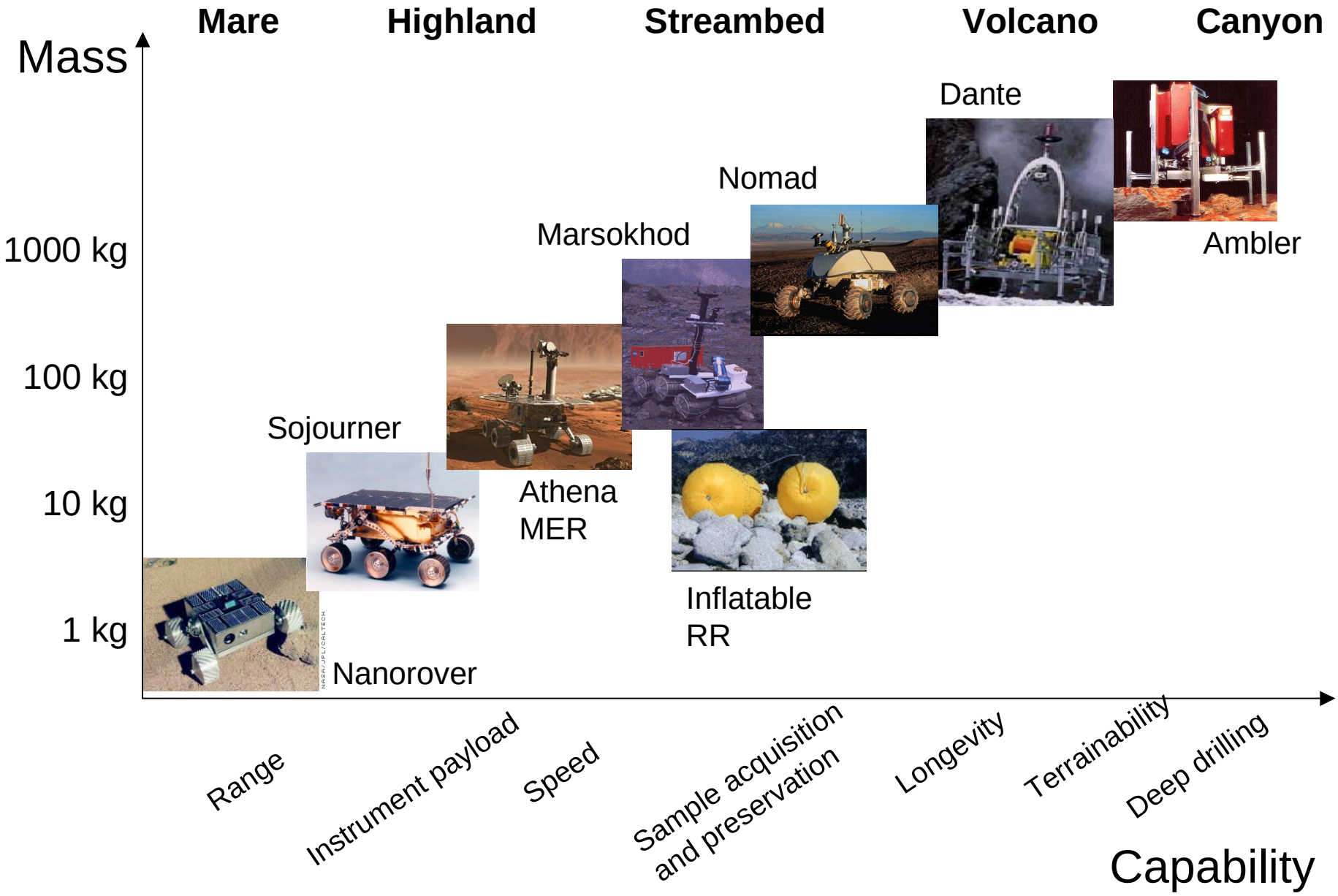
Meteorobot, Elephant Moraine, Antarctica, 2000

Hyperion, Devon Island, Canadian Arctic, 2001

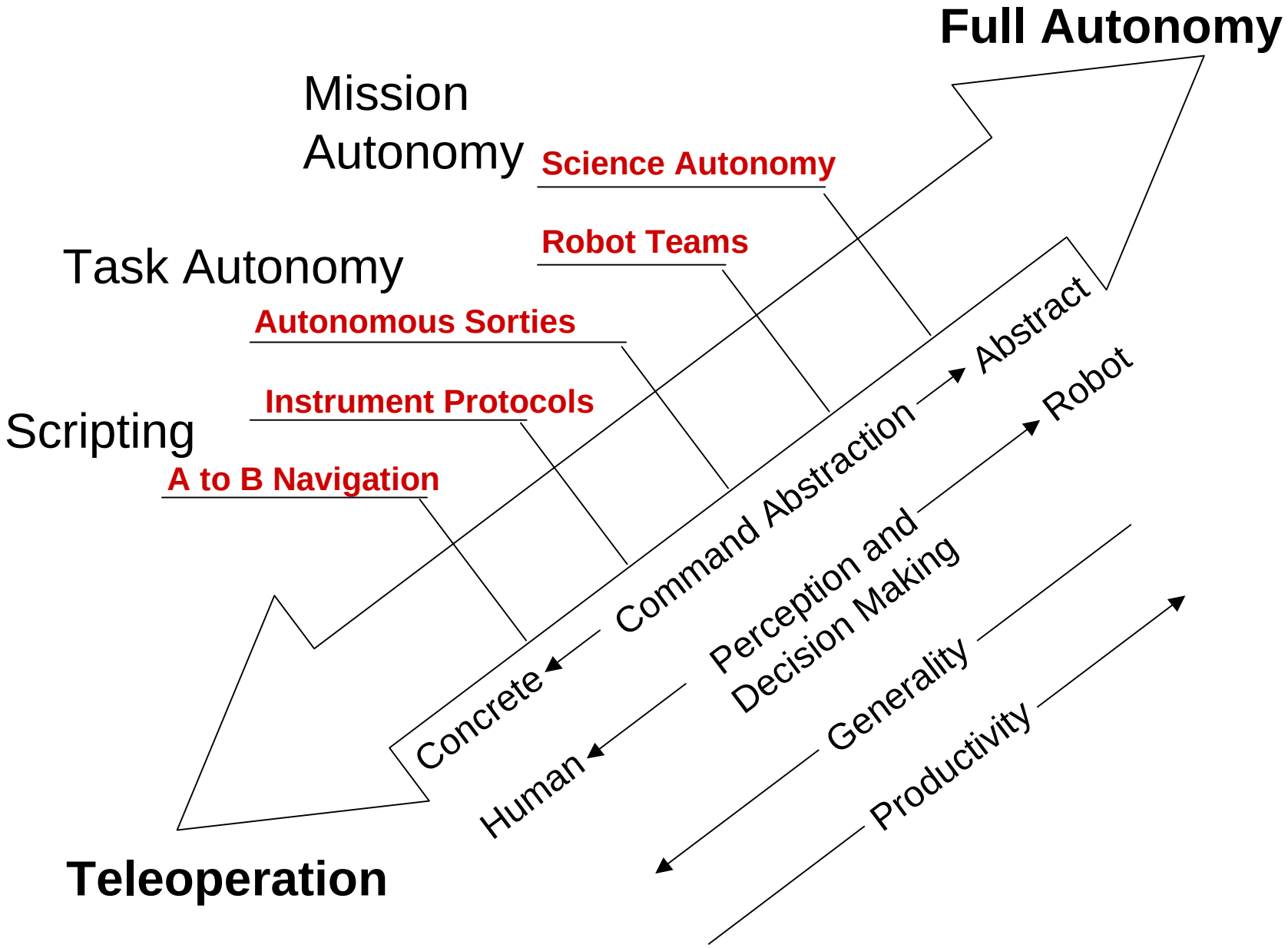
Competencies

- Systems: design, mechatronics, control
- Intelligence: planning, learning, knowledge understanding, classification
- Computer vision: sensors, processing, image understanding
- Navigation: mapping, driving, exploration
- Action: basic manipulation, specialized tool deployment, earthmoving

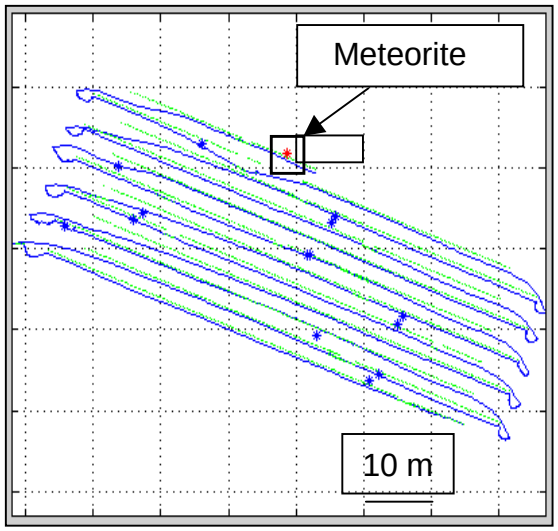
Mobility


Mare
Highland
Streambed
Volcano
Canyon
Mass
1000 kg
100 kg
10 kg
1 kg
Dante
Nomad
Marsokhod
Ambler
Sojourner
Athena
MER
Inflatable
RR
Nanorover
Range
Instrument payload
Speed
Sample acquisition
and preservation
Longevity
Terrainability
Deep drilling
Capability

Autonomy


Full Autonomy
Mission Autonomy
Science Autonomy
Robot Teams
Task Autonomy
Autonomous Sorties
Instrument Protocols
Scripting
A to B Navigation
Command Abstraction
Abstract
Robot
Perception and Decision Making
Concrete
Human
Generality
Productivity
Teleoperation

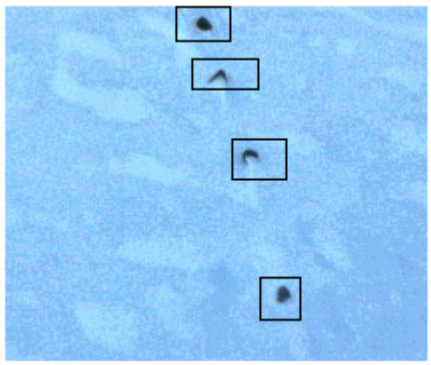
Autonomous Science Technologies



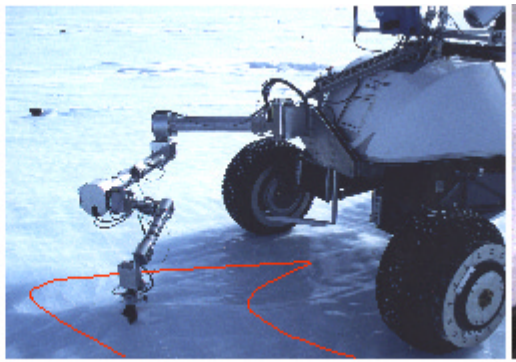
Intra-site and inter-site science

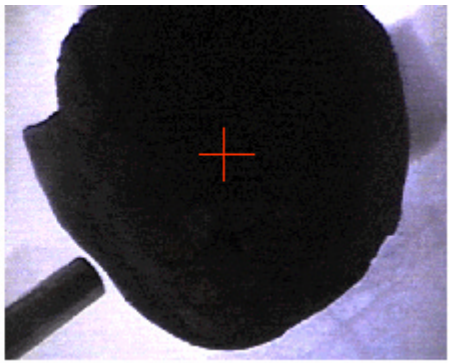
Instruments, manipulators, and drills

- Inter-site traverse and site coverage
- Drills, manipulators, and instruments integrated
- Science Autonomy, classification and experiment protocols
- Sample acquisition and preservation



Science protocols and operations





Sampling and preservation

http://www.frc.ri.cmu.edu/projects/meteorobot2000/

Challenges

- Specialization, integration and fielding
- Biological cleanliness
- Flawless function
- Longevity
- Facile operation
- Dexterity in manipulation & task execution
- Advanced thinking

Robotic Life-Seeking

- Crosscutting technologies and systemic competencies are more common than distinct
- However, each theme requires specialization
- Advanced robotic control, microsystems, data understanding and robust task execution are enabling factors
- Rudimentary robotics for life-seeking in deserts, canyons, volcanoes and hydrothermal environments exist, but serious D&I&V required

Robotics Vision

- Expand frontiers of exploration and science
- Enable new discoveries
- Cause world change
- Cannot replace humans but can *take* humans to the extremes
- Broaden universe of technologies, robots and applications
- Benefit interests of science, space, energy and defense